PROJECT HYDRA-IRIS

by

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ABSTRACT. The Hydra-Iris program is part of the Hydra Research Project being conducted at the Naval Missile Center (NMC), for the RTOS-3 Division of BuWeps. The vehicle is a two-stage system, employing a cluster of three Mk 6 Mod 0 Sparrow motors as a booster and an Iris sustainer that is capable of being launched from any spot on the ocean's surface.

The Naval Ordnance Test Station (NOTS), China Lake, equipped two Hydra-Iris vehicles with payloads designed to telemeter performance functions; to provide an insight into the feasibility of placing scientific payloads in a water-launched vehicle; and to supply telemetry data relating to the in-flight operation and reliability of two infrared radiometers and one ultraviolet radiometer that are so calibrated as to display a gradient or profile of the earth's terrestrial horizon.

Two such vehicles were launched from approximately 500 miles at sea in the Pacific Missile Range on 4 and 8 May 1963, at which time the 121-pound payloads were placed 182 statute miles above the earth's surface. Telemetry was received on the entire first flight. No trajectory was available, and only partial radar tracking was received on the second flight. The data is being analyzed and will be reported separately.

U.S. NAVAL ORDNANCE TEST STATION

China Lake, California

February 1964

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U. S. NAVAL ORDNANCE TEST STATION

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FOREWORD

The Naval Ordnance Test Station was given the opportunity to design and analyze two radiometer-research payloads that are fired from a water-launching environment using the Hydra-Iris vehicle at the Pacific Missile Range.

Foundational Research funding for this project was provided under WepTask R-360-FR106/216-R011-01-01.

The initial work was started in September 1962, and the project was completed in May 1963.

Released by
C. P. SMITH, Head,
Air-to-Air Weapons Div.
20 December 1963

Under authority of
FRANK KNEMEYER, Head,
Weapons Development Dept.

ACKNOWLEDGEMENT

Our appreciation is extended to several persons, without whose help the payload portion of the project could not have been completed.

Mr. D. K. Moore, Head, Code 4052, under whose guidance and direction the program was started; G. A. Wilkins and J. P. Lee, Radiation Physics Lab, for the major portion of the calibration; E. G. Paulsen, in charge of the payload layout and its entire construction; J. O. Randolph, for the basic idea for the watertight optical door; J. A. Hoyem, responsible for data reduction; and those of the fleet and ground support personnel who are too numerous to mention.

NOTS Technical Publication 3391

Published by .... Weapons Development Department
Collation .... Cover, 8 leaves, abstract cards
First printing .... 110 numbered copies
Security classification .... UNCLASSIFIED

INTRODUCTION

In early September 1962, the U. S. Naval Ordnance Test Station (NOTS), China Lake, was advised that payload space would be available on two water-launched probes, if it could be properly utilized. The research vehicle, Hydra-Iris, was part of the Hydra program being conducted at the Naval Missile Center (NMC), Pt. Mugu. The two-stage ballistic probe comprised an Atlantic Research Corp. Iris end-burning motor as a sustainer and an NMC-developed cluster of three Sparrow motors as a booster.

The launching was to be at sea from a zero-length, underwater, floating tower that required a watertight payload package.

The vehicle was equipped with a three-radiometer research and evaluation payload that furnished inputs for all necessary motor functions that were telemetered to the ground. Appendix A contains a more complete discussion of the spectral region of the radiometer.

The NOTS-developed payloads were completed in January 1963. They used a 19- by 12-inch-diameter space made available in the 21-inch, nose-cone extension on the vehicle. The 21-inch extension tube was modified, equipped with a waterproof optical window, and used as the payload shroud.

Problems in range-scheduling did not permit firings until May 1963, at which time, both test vehicles and payloads were successfully launched, and the experimental portion of the Hydra-Iris project was closed.

Schedule requirements were so critical that it was decided to construct the radiometers from surplus components that were available. This somewhat restricted the choices that were available for optical design of the radiometers, although the final designs closely approached those achievable on a less rushed schedule.

The two Hydra-Iris payloads incorporated identical radiometer sets. For these, the view fields were small and of nominal dimensions:

8-13-micron channel, 2 by 2 deg,

2.7-micron channel, 24 by 24 mr,

2700-Å channel, 10 by 10 mr.

Hydra-Iris was designed to fly a nearly vertical trajectory. Preflight plans specified that the vehicle spin should cause all radiometer-scan planes to cut shallow chords across the disk of the earth. For each scan period, an appreciable fraction would be spent with the radiometer view field near, but just below, the horizon. It was felt that this would increase the effective resolution with which the terrestrial horizon would be studied.

LAUNCHER

The launcher used for this series of firings was a free-floating configuration, triangular in shape, made of stainless-steel tubing and rails with a polystyrofoam floatation device near the muzzle (Fig. 1). A standard crane and rig can be used to handle the loaded launcher aboard ship. Standard missile dollies were also used to load the launcher.[1]

A coded radio link was employed as a remote-firing system. The receiver on the launcher accepted various combinations of inter-range instrumentation group (IRIG) tones, 1 through 5, to turn the payload off and on, to arm the missile, and to fire it. An umbilical between the command receiver and the interstage carried the firing signal to the missile.

Wave action, causing launcher-pitch movement, was considered in the initial launcher design. The launching angle is obviously a function of sea conditions. The first firing indicated that a sea state of 1 could produce near-vertical launches.

VEHICLE

The Hydra–Iris is a two-stage ballistic probe employing a cluster of three Sparrow III Mk 6 Mod 0 motors as a booster, and a three-finned, 12.75-inch, Iris, end-burning motor as the sustainer. Both booster and sustainer were waterproofed for use in the Hydra program. The entire vehicle is 326 inches in length.[2]

The booster igniters were manifolded for simultaneous ignition and pressure equalization of the motors. This adaptation was a NMC design to provide a booster that would fit between the rails of the launcher and still boost the Iris vehicle to a velocity sufficient to make it aerodynamically stable. The sustainer is ignited with the booster, and drag separation occurs at approximately 1,000 feet.

[1,2]For further launcher description see Naval Missile Center. Summary of Development of Hydra–Iris System. (NMC Technical Report 63-2; to be published.)

The Iris sustainer burns for 52 seconds and produces approximately 4,000 pounds of thrust that result in Iris burnout at 170,000 feet. Radar tracking indicated an apogee of 182.4 statute miles on the firing of 4 May 1963. Apogee occurred at a position 15 miles downrange from the launching site, indicating a near-vertical trajectory.

Motor functions and flight performance were monitored through the payload's telemetry system during the burn phase of the flight. These inputs included such things as pressure, temperature, vibration, acceleration, and spin rate, and will be discussed later in this report.

The payload occupied space in a 21-inch cylindrical extension to the nose cone. The nose cone is an 80-inch tangent ogive 5:1, with a 12.50-inch diameter. This nose cone supports a 1/4-wave-spike telemetry antenna at the tip of the cone, two S-band beacon antennas in the after section, and three temperature sensors placed to measure skin temperature as well as free-air temperature in the nose-cone area.

PAYLOAD

The three spin-modulated radiometers were mounted in the payload, all looking at an angle 10 degrees aft of the plane and perpendicular to the spin axis.

The 8- to 13-micron system consisted of a Barnes 0.1- by 0.1-mm thermistor-bolometer-immersed detector that was mounted in a 2 1/2-inch-diameter by 3-inch focal-length, prime-focus-reflector telescope. The filter was manufactured by the Optical Coating Laboratory, Inc., and displays a bandwidth from 8.73 to 12.8 micron at the 50-percent points. The radiometer has a plotted, 2-degree field of view.

A semiconductor amplifier with a 3- to 900-cps bandpass at the 3-db points was used to drive the subcarrier oscillators. Bias for the detector was provided by a 180-volt, dry-battery pack.

The telescope was focused using a collimated beam from a black-body source. When the point of best focus was found, the entire detector-mounting spider was potted in place.

Thermistors were placed in the 8- to 13-micron amplifier, and on the detector mount, as a means of sampling in-flight temperatures.

A 1- by 1-mm lead sulphide detector was filtered to look in the 2.7-micron, water-vapor absorption band, and was mounted in a telescope that was identical to the one used in the 8- to 13-micron radiometer. A similar amplifier was also used, and modified to obtain proper bias for the detector.

A thermistor was mounted in the 2.7-micron amplifier case for temperature measurements.

A simple quartz lens, refractor telescope was used with a 1P28 photomultiplier tube to provide the basis of the 2700-Å ultraviolet radiometer. The telescope was focused at infinity, and a field stop was used to obtain a 10-mr field of view. The telescope was primarily used for view-field definition, rather than for optical gain.

A 25-mm-thick NOTS-developed UV filter was employed in the barrel of the telescope to obtain a narrow optical bandwidth.

The PM tube, complete with its voltage divider network, was potted in an aluminum housing. High voltage for the dynode chain in the tube was furnished from a 930-volt transistorized d.c.-d.c. converter. A low-gain-semiconductor amplifier was used with this radiometer.

The telemetry system in the payload had a dual function: to provide vehicle-performance data as a means of evaluating this application of the Hydra probe, especially during the burn phase of the flight; and to telemeter the radiometer and payload information.

Continuous vehicle-spin information was obtained from a Schoensted RAM-3 Magnetic Aspect Sensor. Other continuous channels included motor-pressure measurements and linear acceleration. Temperature measurements were taken as part of the commutated information.

Three axis-vibration data were recorded on wide-band-telemetry channels throughout the powered portion of flight. At burnout, these three channels were switched to the three radiometer inputs for the remainder of the flight. This was done in an effort to secure the optimum usage of the high-frequency-telemetry channels, and to eliminate the need for a second telemetry system.

Temperatures, voltage monitors, and optical door-separation information from the payload were also placed on the commutated channel.

The physical payload was 12 inches in diameter and 19 inches long (Fig. 2 and 3). All instrument decks were supplied with an interconnecting cable harness for easy removal, although radiometer-output cables and pyrotechnic leads were wired directly.

The block diagram (Fig. 4) shows the general structure of the payload. The telemetry package was a straightforward FM-FM system feeding a single 1/4-wavelength-spike antenna in the nose cone.

The antenna was a mild steel rod, vertically polarized, with the major lobe aft of the motor system. The VSWR was 1.3:1 as measured on a Rhode and Schwartz diagraph.

Because the payload section and most of the nose cone are underwater in the launching condition, it is necessary to pressurize these areas. This requires the design of a watertight port that could be removed in flight to provide an air-path window from which the optical instruments could scan the earth. Sealed, nonremovable, glass quartz, or sapphire windows were avoided because of their optical filtering characteristics in the spectral regions that are under study. A waterproof door, released by unlatching a spring-steel band, was designed to seal the window that was cut in the payload shroud. The shroud also served as the 21-inch extension to the nose cone, and was bolted directly to the Iris motor.

Two independent timers were used to control payload functions. The first timer released the watertight door at approximately the time of motor burnout. The second timer had a built-in delay so that it could not operate for the major portion of the motor's burning time. After burnout, decrease in acceleration caused the timer to function, switching the telemetry inputs from motor-vibration transducers to the three radiometer channels. Both timers are commercially available, mechanical units that drive a cam and microswitches.

The power pack for the payload used Yardney silver cells as the 28-volt and 6-volt primary sources. Total battery life without recharging is one hour.

Twenty-eight volts were supplied to the transmitter, SCO's, thermistor networks, and to a commercial d.c.-d.c. converter. The three converter outputs were -930 volts that operated the PM tube and its Victoreen diode regulator; 28 volts that fed a 20-volt, semiconductor regulator and associated radiometer amplifiers; and -28 volts that regulated to -20 volts through a Zener diode for bias requirements.

The 6-volt, primary source operated the commutator drive system, and the magnetic-aspect-sensor power supply, and furnished voltages to fire the electric switches and bolt releases. Six volts were also supplied for the portion of the payload occupied by NMC as the primary power for their motor system's telemetry.

RADAR-BEACON PACKAGE

An S-band beacon was included as part of the vehicle instrumentation by the NMC to provide accurate radar-tracking and missile-trajectory information. The entire beacon package and its battery pack was mounted on a platform forward of the payload, using the payload shroud as a mounting base.

Peak pulse power of 2 KW was obtained from an A/N DPW-1 (XE-2) beacon system feeding a dual, ground-plane-antenna array near the base of the nose cone.

CALIBRATION

Calibration of the payloads was accomplished at the Radiation Physics Laboratory at China Lake, and at the NMC.

All motor-function transducers, voltage monitors, vibration-measurement devices, accelerometers, and temperature sensors, external to the payload, were calibrated at the NMC. The magnetic-aspect sensor was calibrated at the factory.

All payload temperature sensors, and switch and voltage monitors in the payload were calibrated at NOTS in conjunction with the optical calibration.

The infrared radiometers were measured in a closed, purged system that utilized a hot-cold environmental chamber, a Ransom 5-inch-diameter by 25-inch focal-length collimator with cooled aperture and a Barnes black-body source, and a pulse and sinusoidal external-chopping system. The chamber was stabilized at 25°C throughout the calibration procedure. Output from each infrared radiometer was recorded at several discrete energy levels that ranged from 1:1 S + N/N to saturation of the system. Background noise was also measured.

The ultraviolet radiometer was calibrated using much the same system, except that a purged environment was not necessary. The source was a ribbon-filament incandescent lamp that operated with a high-current, 400-cps power supply. The lamp was compared with a secondary standard before and after the calibration.

Since the main objective of the radiometers was to produce a gradient of the earth's horizon, information about the frequency response of the radiometer system was given prime consideration in calibration, and a crude, absolute-energy-level calibration was made to ensure that

the system would not be saturated. The frequency response of the entire optical-electrical detector system was measured using a source interrupted by a variable-speed, sinusoidal-chopper blade. In addition to this, a pulse type of chopper was used to simulate the actual flight's scanning mode. Frequency response was again measured by this system.

Fields of view of each instrument were also carefully measured as this affects the response required of each radiometer.

All video-calibration data were recorded directly on magnetic tape.

FIRINGS

Both Hydra–Iris vehicles were launched in May 1963; the first at 1215 PDT on 4 May, and the second at 0913 PDT on 8 May.

The first firing was launched with surface winds of 10 to 15 knots and a sea state of 1. Radar tracking was available from burnout through apogee, which occurred at 182.4 statute miles above the surface and at a position approximately 15 miles downrange. The payload weight, including the beacon system, was 121 pounds. Telemetry was recorded for the entire flight of the vehicle, and good motor information was received on the burning portion of the flight. The optical-door release functioned at 44.2 seconds after launching, and the motor-vibration–radiometer-selector switch operated at 70.6 seconds. This time was somewhat delayed, and it is attributed to a sluggish gear train in the mechanical timer. The timer should have functioned at burnout, which took place at approximately 55 seconds after launching.

The second firing took place with 8- to 10-knot surface winds and a sea state of 2. Only a partial radar tracking was secured, and no trajectory was available. The payload was essentially identical in all respects to the first unit.

Telemetry was received for 110 seconds after launching, at which time all contact was lost with the payload. An analysis of the records is continuing to determine the cause of the failure.

Figures 5, 6, and 7 show a typical launching, using a booster system, dummy Iris motor, and no payload. The camera tower next to the launcher is not used during a live firing.

RESULTS AND RECOMMENDATIONS

Telemetry data from the radiometers on the firing of 4 May 1963 indicate that the optical-door release on the payload functioned properly; however, the individual radiometer channels display only cell and system noise. It is possible that the optical door jammed on its release and failed to clear the window area needed by the optical systems.

Good motor-operation data were received during the burn phase of the flight. Motor functions were not analyzed at NOTS, China Lake, but will appear in the NMC, Pt. Mugu, report previously cited.

Magnetic-aspect-sensor information from this flight is being analyzed by the Aeromechanics Division at China Lake to determine the amount of perturbation present during the coast phases of the flight. This information will be useful in the design of optical systems and their associated fields of view, payload-separation devices, etc., for use on similar high-altitude probes.

The telemetry record of the Hydra—Iris flight of 8 May 1963 reported similar motor information, and in addition, contained approximately 50 seconds of video information from the 2.7-micron radiometer, partial information from the 8- to 13-micron radiometer, and no information from the ultraviolet scanner. These data will be analyzed and reported separately.

Early in the program, it was recommended that temperature studies be made to examine the effect of nose-cone heating. A theoretical study revealed possible temperature in the neighborhood of 600°F, with no apparent failure to be expected in the nose-cone structure. Preliminary analysis of in-flight telemetry data from high-temperature thermistor sensors that are mounted in three areas of the nose cone appears to substantiate this study. The final temperature analysis is the subject of another report.

It may be concluded from the data received that this type of water-launched vehicle exhibits characteristics that are compatible with the requirements of rather sensitive research payloads. Water exit appears smooth; vibration and acceleration are relatively mild; and payload sections can be water-proofed properly, yet they possess removable doors or ports that are needed for optical scanners. Although there was an abrupt loss of telemetry during the second flight, there is no evidence that the antenna systems were degraded by the salt-water environment.

The following photographs show the missile in various phases of test, specific parts callouts, and a block diagram.

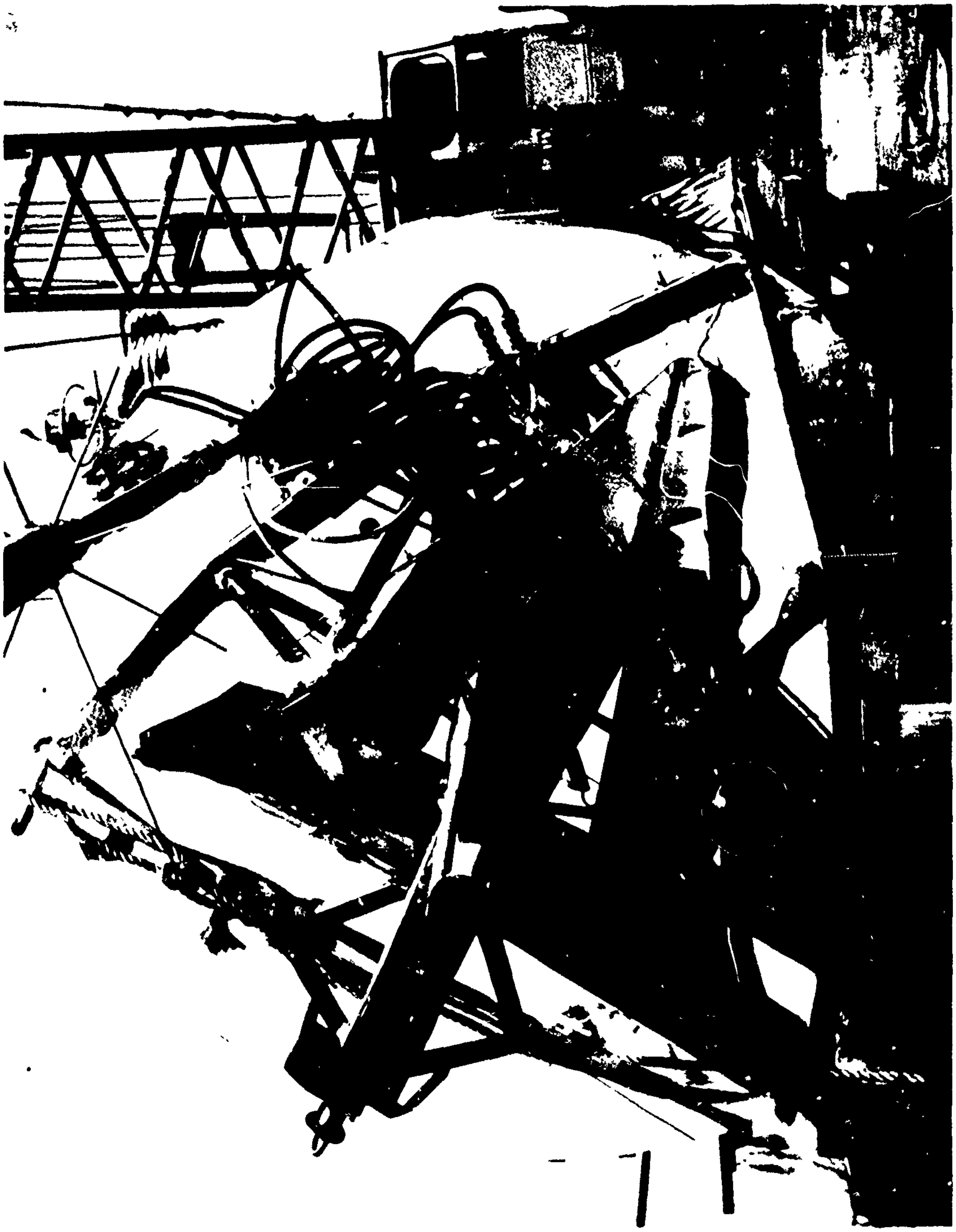

Fig. 1. Hydra-Iris Test Vehicle and Launcher Mounted in Floatation Ring. (Aboard ship before launching.)

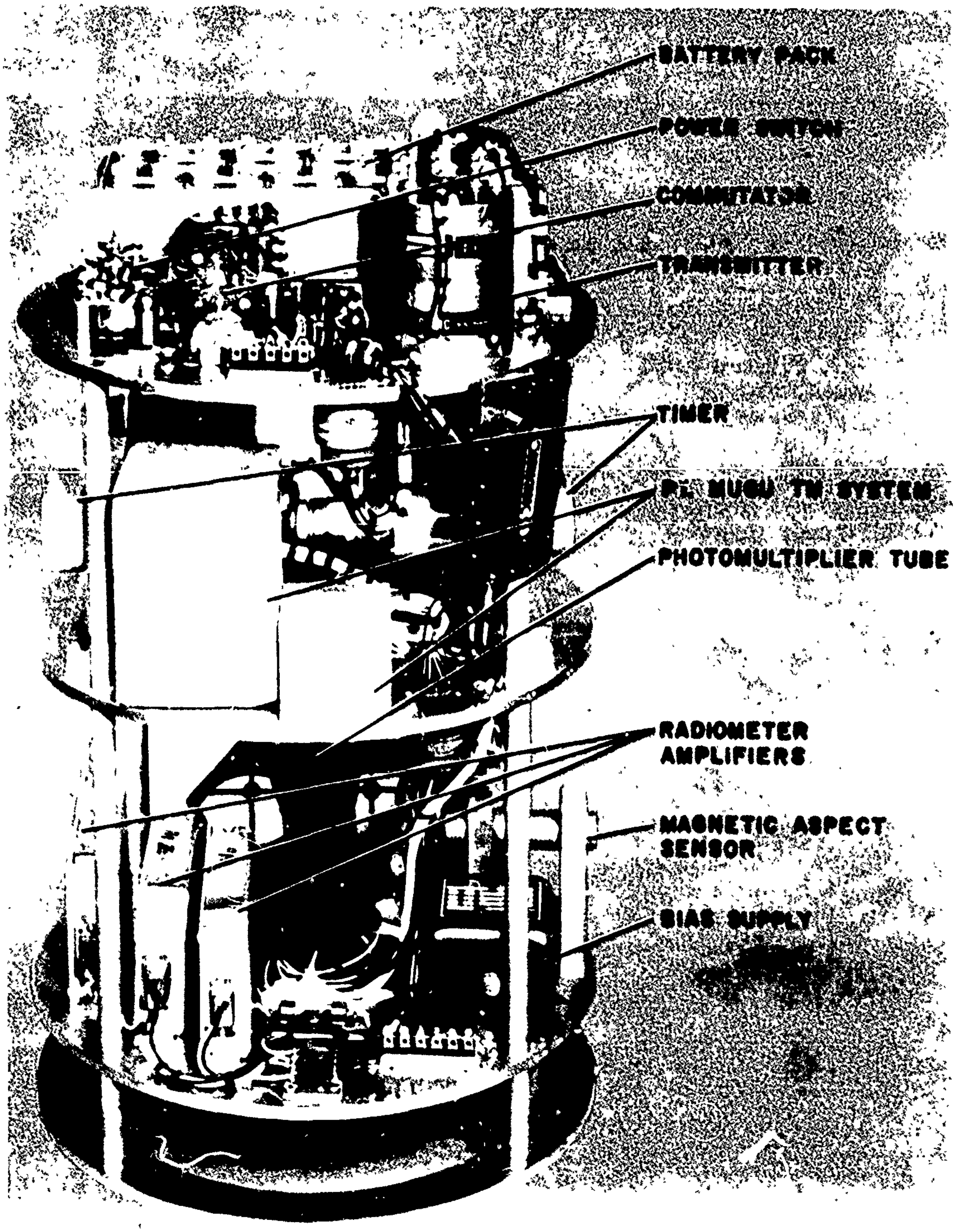

Fig. 2. Hydra-Iris Payload, Forward View.

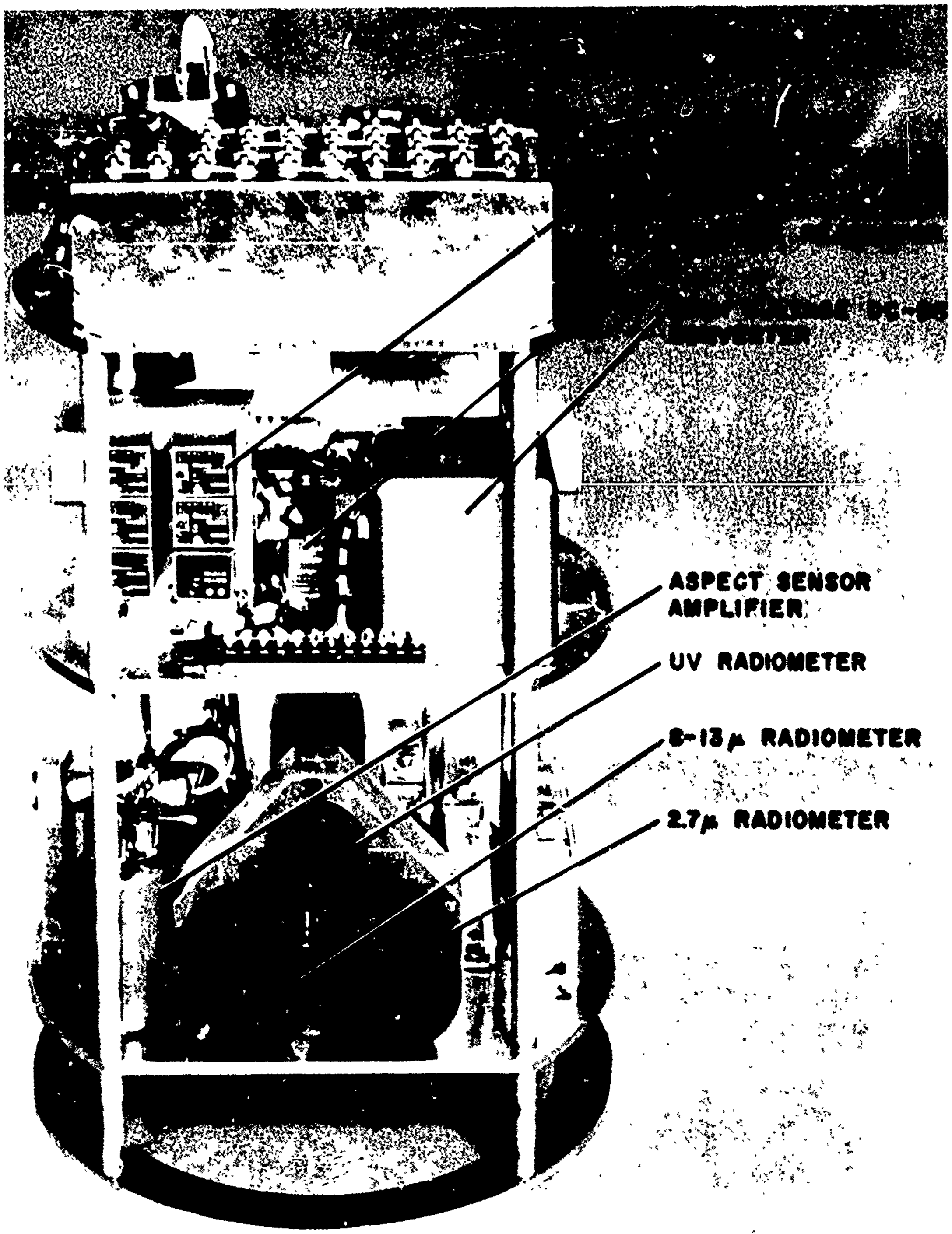

Fig. 3. Hydra-Iris Payload, Rear View.

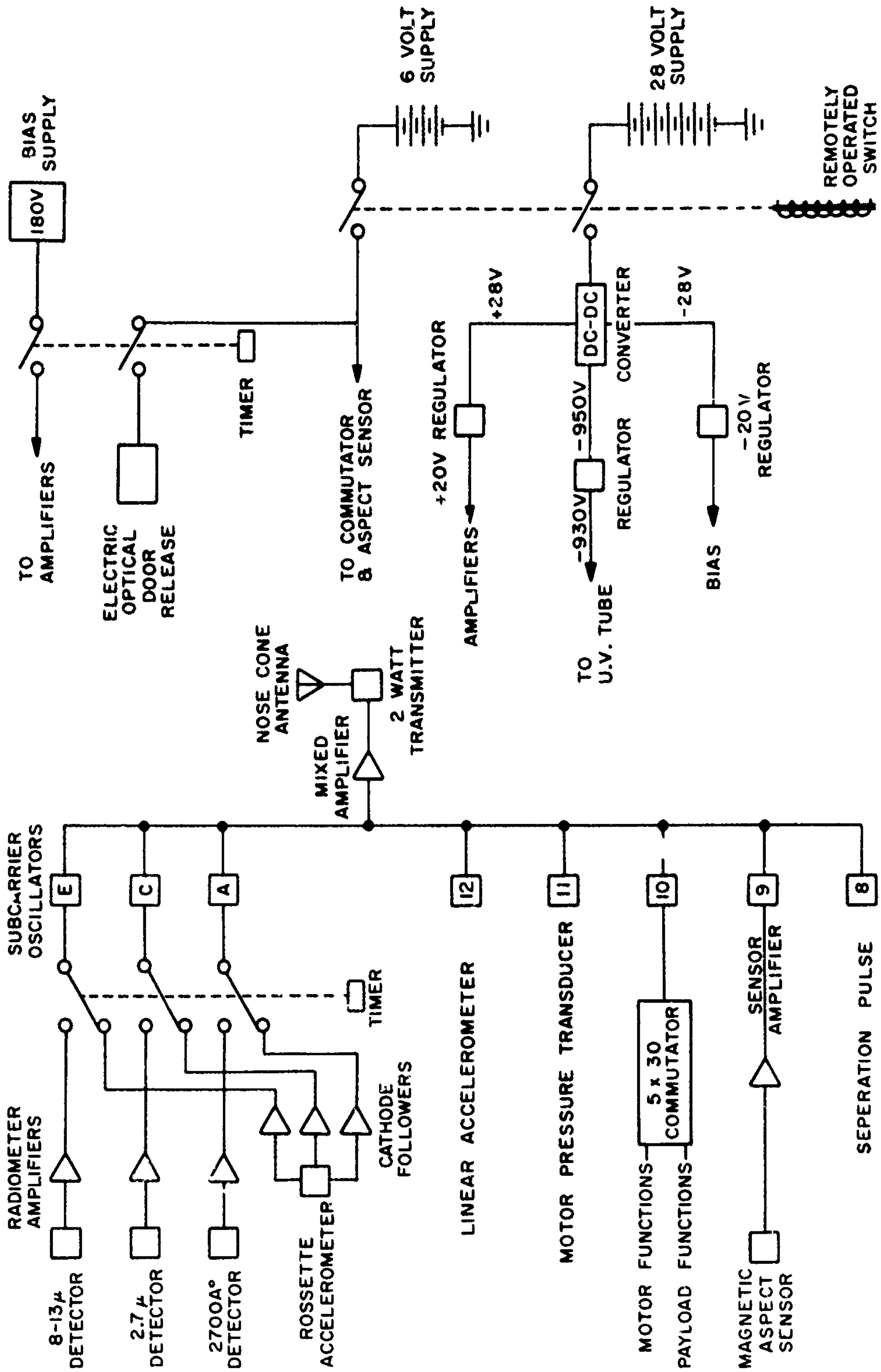

Fig. 4. Hydra–Iris Telemetry System, Block Diagram.

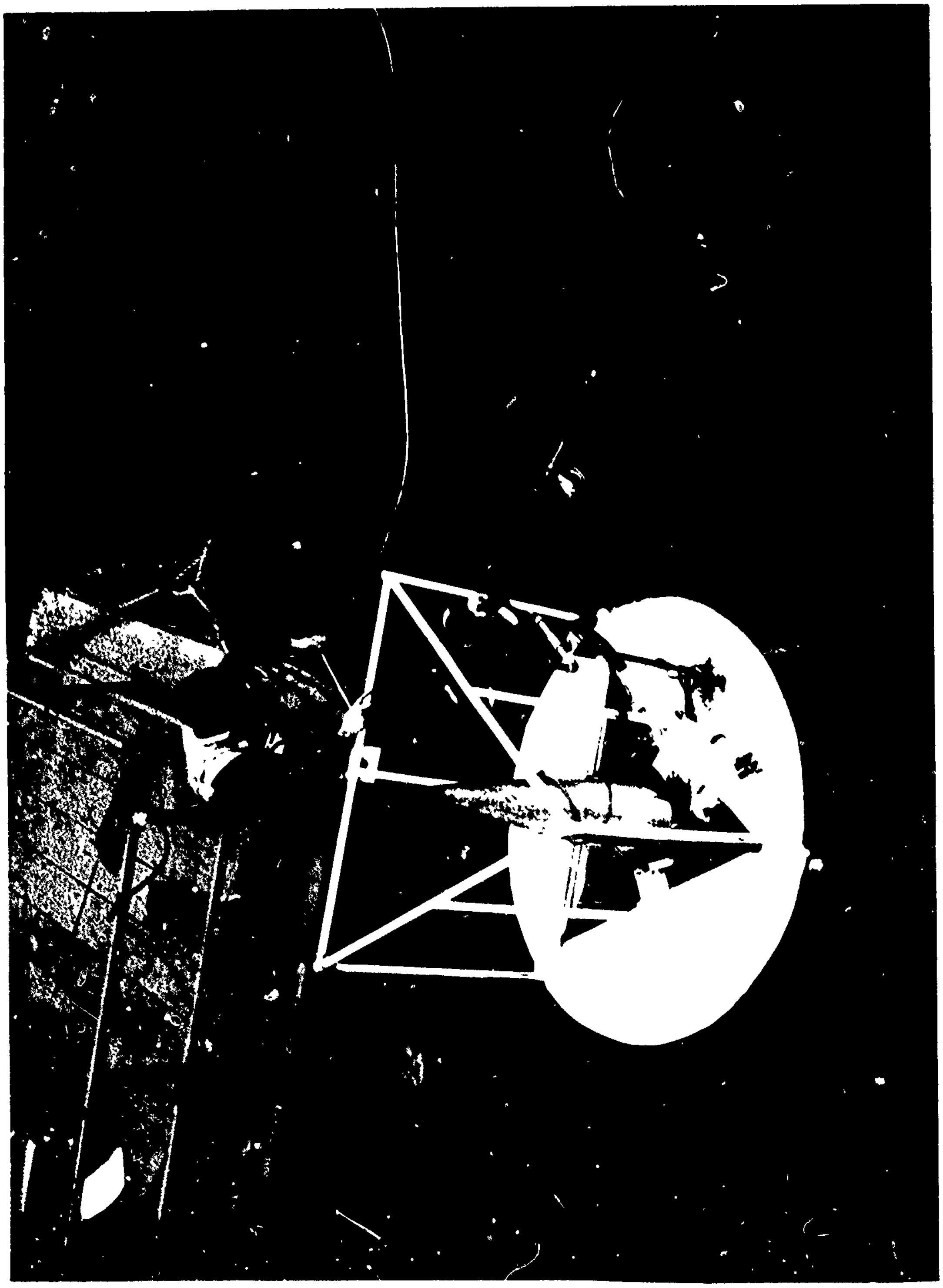

Fig. 5. Hydra-Iris Vehicle in Floatation Ring, Before Firing.

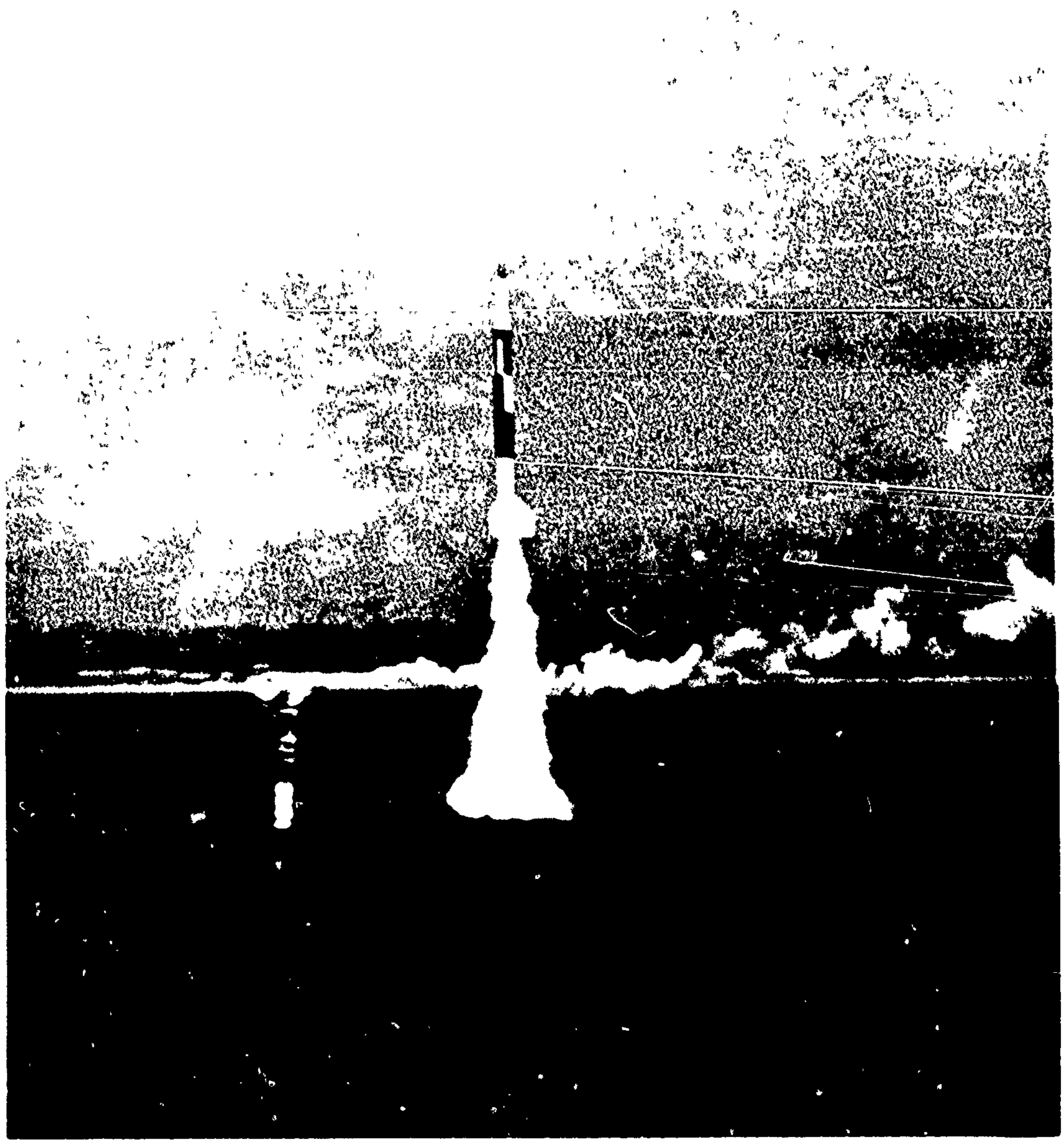

Fig. 6. Test Firing of Hydra-Iris.

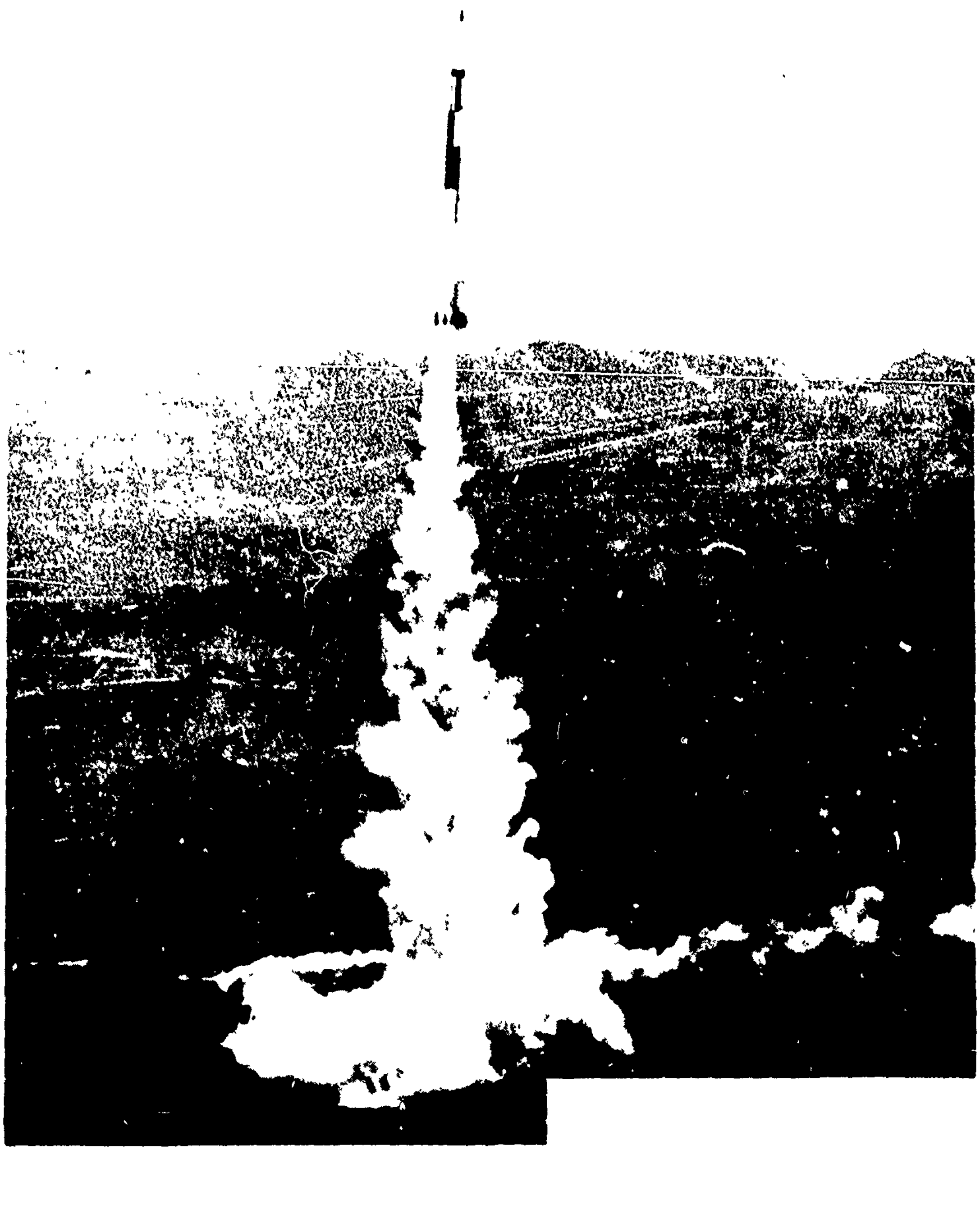

Fig. 7. Test Firing of Hydra-Iris.

Appendix A
SPECTRAL INTERVALS

For these measurements, three discrete—and widely separated—spectral intervals were chosen. Each was theoretically characterized by a unique mode of horizon-radiance excitation.

ULTRAVIOLET, 2600–2800 Å

In this wavelength interval, two highly competitive processes determine the magnitude and spatial distribution of the horizon radiance. Rayleigh scattering, varying as the inverse fourth power of wavelength, would be expected to appreciably increase the brightness of the horizon at shorter wavelengths. Ozone absorption would be almost totally complete below an altitude of about 35 kilometers. The horizon, at this wavelength, would appear as a smooth arc, physically separated from the solid earth mass below. The angular thickness of the arc was not known.

INTERMEDIATE INFRARED, 2.7 MICRONS

The filter used for this radiometer had its spectral bandpass centered within the H_2O–CO_2 absorption band. Solar-radiation scattering, except from clouds, would not be appreciable at this wavelength—even clouds would be hidden within the absorbing atmosphere, if below about 30,000 feet. The smoothness of the horizon arc that is visible at 2.7 microns would be governed by the abundance and vertical distribution of terrestrial clouds. A slight angular separation of this arc from the earth mass below would be expected.

INFRARED, 8–13 MICRONS

At these wavelengths, contributions by scattered or reflected solar radiation would be completely negligible in any measurement of horizon radiance. If treated as gray-body-radiation sources, most levels of the atmosphere would show emittance peaks within the spectral bandpass of this radiometer (corresponding to air-mass temperatures between 220 and and 360°K). Since this interval represents a relatively clear atmospheric window, emittance from the earth mass would be a major contributor to background radiance. At the horizon, the smooth arc of the earth surface would be modified by direct radiation from clouds. The disruption of the arc by these radiating cloud sources could be appreciable.

ABSTRACT CARD

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